U.S. Department of the Interior
U.S. Geological Survey

Water-Quality Assessment of the Trinity River Basin, Texas— Nutrients in Streams Draining an Agricultural and an Urban Area, 1993–95

Open-File Report 96–322

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Abstract

Water samples collected from streams draining an agricultural area in the west-central part of the Trinity River Basin upstream from the Richland-Chambers Reservoir and from streams draining an urban area in the Dallas-Fort Worth metropolitan area during March 1993–September 1995 were analyzed for nutrients (nitrogen and phosphorus compounds). A comparison of the data for agricultural and urban streams shows the maximum concentration of total nitrogen is from an urban stream and the maximum concentration of total phosphorus is from an agricultural stream. One-half of the samples have total nitrogen concentrations equal to or less than 1.1 and 1.0 milligrams per liter in the agricultural and urban streams, respectively; and one-half of the samples have total phosphorous concentrations equal to or less than 0.04 and 0.05 milligram per liter in the agricultural and urban streams, respectively. The highest concentrations of total nitrogen in both types of streams are in the spring. The minimum concentrations of total nitrogen are during the summer in the agricultural streams and during the winter in the urban streams. Concentrations of total phosphorus in agricultural streams show negligible seasonal variability. The highest concentrations of total phosphorus are in spring and possibly late summer in the urban streams. In the midrange of streamflow in the urban streams and throughout the range of streamflow in the agricultural streams, concentrations of total nitrogen increase. Concentrations of total phosphorus increase with streamflow in the middle and upper ranges of streamflow in both agricultural and urban streams.

Introduction

In 1991, the U.S. Geological Survey (USGS) began nationwide implementation of the National Water-Quality Assessment (NAWQA) Program. Long-term goals of NAWQA are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Leahy and others, 1990). The Trinity River Basin (fig. 1) is among the first 20 study units to be assessed as a part of this program. The stream assessment is made by sampling water, bed sediment, and tissue of biota and characterizing the aquatic communities and their habitat. The aquifer assessment is made by sampling wells. The first intensive data-collection phase began in March 1993 and ended in September 1995.

The NAWQA program involves sampling and studying a wide range of potential contaminants in streams and aquifers. For the 1991 study units, emphasis is on assessing nutrients, suspended sediments, and pesticides in watersheds with rather uniform environmental settings. In the Trinity River Basin, nonpoint sources of

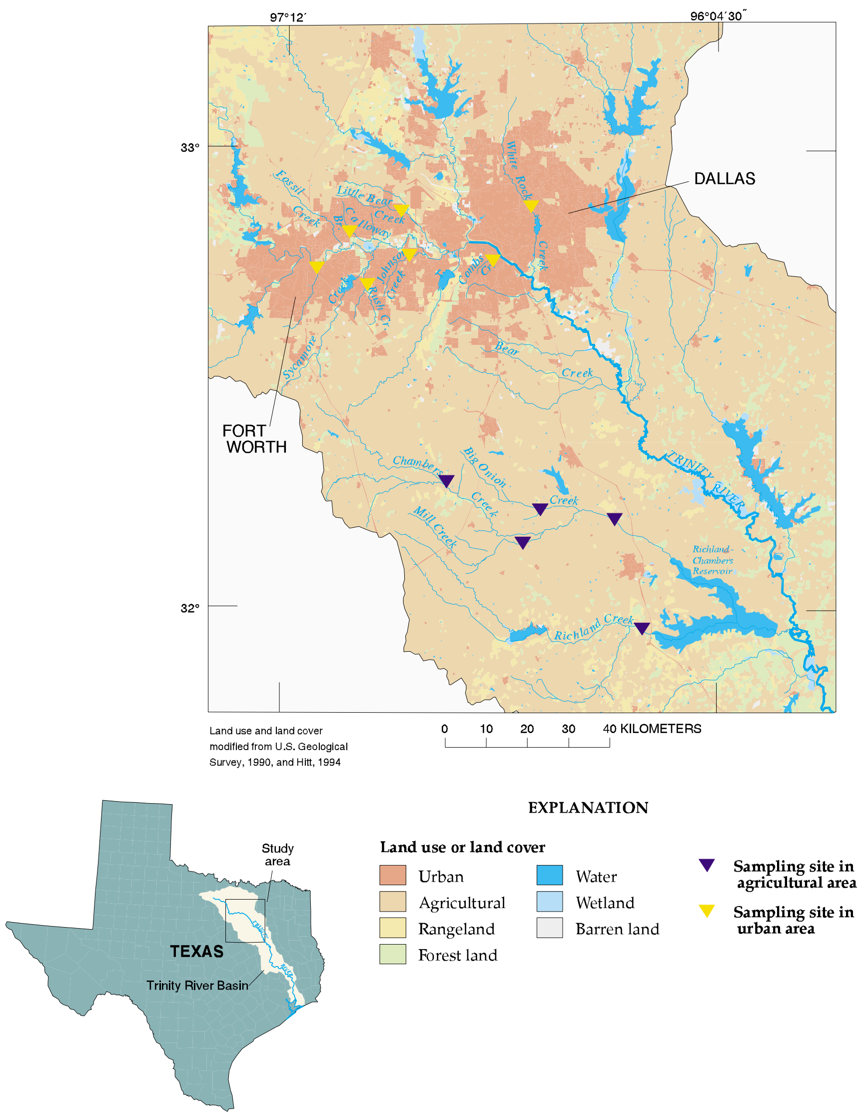

Figure 1. Location of Trinity River Basin and sampling sites.

contaminants from agricultural and urban watersheds are of considerable interest to a study-unit liaison committee comprising representatives from Federal, State, and local agencies and others who have water-resource responsibilities and expertise. Nutrients (nitrogen and phosphorus compounds) are of concern because (1) warm-blooded animals are harmed if they drink water with high concentrations of nitrate (greater than 10 milligrams per liter [mg/L] as nitrogen) and (2) excessive nutrient concentrations in streams and reservoirs can contribute to unusually large amounts of algae and other aquatic plants, which can lead to eutrophication, impaired recreational use, foul taste and odor of the water, and large swings in dissolved oxygen concentrations.

The purpose of this report is to compare the nutrients in streams draining an agricultural area and an urban area by showing the distributions of nutrient concentrations and how the concentrations vary with seasons and streamflow. A comprehensive analysis of nutrient data collected in the Trinity River Basin during 1974–91 is given by Van Metre and Reutter (1995).

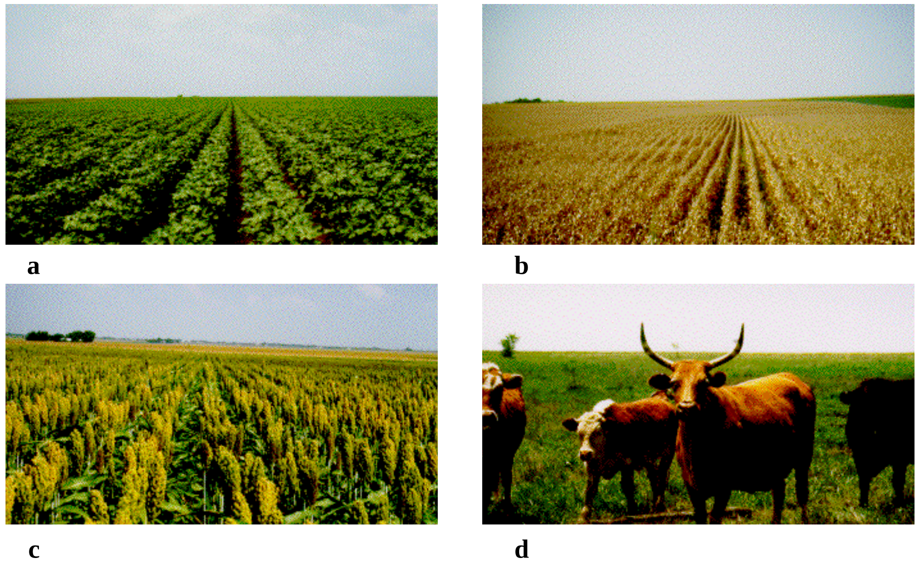

Figure 2. Land uses in agricultural area: (a) cotton, (b) corn, (c) sorghum, and (d) rangeland with cattle.

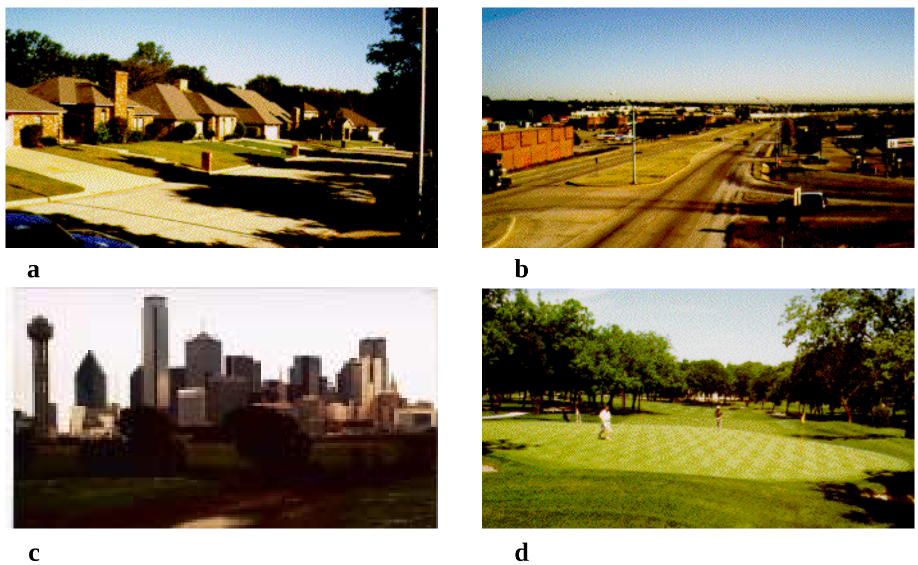

Figure 3. Land uses in urban area: (a) residential, (b) transportation and commercial, (c) flood plain and commercial, and (d) recreation.

Study Areas

The agricultural area is upstream of the Richland-Chambers Reservoir in the west-central part of the Trinity River Basin (fig. 1). In this agricultural area, land uses are mostly cropland, pasture, and rangeland (fig. 2). Major crops are corn, cotton, and sorghum, which are grown without irrigation. Hay also is grown along with grass for cattle, the dominant livestock. The watershed areas upstream of the five sampling sites range from 150 to 2,150 square kilometers (km^2).

The urban area is in the Dallas-Fort Worth metropolitan area (fig. 1). Land use in the watersheds upstream of the seven sampling sites (fig. 3) is dominated by single-family residences; but some multi-family residential and commercial areas—shopping centers and office complexes—are along major streets and highways, and some agriculture exists in the headwaters of four watersheds. None of the watersheds has wastewater-treatment plants or other major point sources of nutrients. The watershed areas upstream of the sampling sites range from 13 to 174 km^2.

Approach to Analysis

Nutrient data for this analysis were aggregated from data collected at the 5 sites in the agricultural area and at the 7 sites in the urban area (fig. 1). Data were collected during March 1993–September 1995. All of the sites had 6 to 10 samples, except for two sites (one in each area) at which about 40 samples were collected. In all, data from about 80 samples in each area were available for analysis. Late winter to early summer sampling was emphasized because that period is when most fertilizers and pesticides are applied and when runoff events are most common.

Graphical analyses are used to compare nutrient concentrations in streams draining the two types of area. The distributions of selected compounds of nutrients are shown with boxplots. The boxplots show the minimum, 25th percentile, median, 75th percentile, and maximum concentrations. The seasonal variability of total nitrogen and total phosphorus is shown by x-y plots of date and concentration, without regard to year. The relations of nutrient concentrations to streamflow are shown with x-y plots. A LOcally WEighted Scatterplot Smoothing (LOWESS) line (Cleveland, 1979, *in*

Helsel and Hirsch, 1992) is superimposed to highlight trends or patterns in concentration relative to season and streamflow.

Nutrients in Streams Draining an Agricultural and an Urban Area

Nutrients in streams include several compounds of nitrogen and phosphorus that can be dissolved in water or attached to suspended sediment. Their concentrations are influenced by many environmental and human factors, such as season, instream processes, soils, proximity to sources, and land use.

Concentrations

Boxplots (fig. 4) facilitate comparison of concentrations of several dissolved and total (dissolved plus suspended) nitrogen and phosphorus compounds between agricultural and urban streams. For nitrogen compounds, the median concentrations in samples from agricultural and urban streams differ by about 0.1 mg/L as nitrogen or less. For total nitrogen, the median concentrations are 1.1 and 1.0 mg/L as nitrogen in the samples from agricultural and urban streams, respectively. Seventy-fifth-percentile concentrations of dissolved ammonia, dissolved ammonia plus organic nitrogen (known as dissolved Kjeldahl nitrogen [DKN]), and total ammonia plus organic nitrogen (known as total Kjeldahl nitrogen [TKN]) are greater in the samples from urban streams. Nitrite, nitrite plus nitrate, and total nitrogen concentrations at the 75th percentile are greater in the samples from agricultural streams. Maximum concentrations of all nitrogen compounds, except for nitrite, are greater in the samples from urban streams. At the median concentrations, about 80 percent of the total nitrogen in samples from streams draining both areas is in the dissolved form.

The median concentrations of phosphorus compounds in agricultural and urban streams have concentrations equal to or less than 0.04 and 0.05 mg/L in agricultural and urban streams, respectively. Seventy-fifth-percentile concentrations are 1.5 to 2 times greater in the urban streams than in the agricultural streams. At the median concentrations, dissolved phosphorus makes up about one-half of the total phosphorus in both types of streams.

The U.S. Environmental Protection Agency (USEPA) has established a maximum contaminant level (MCL) for drinking water of 10 mg/L of nitrate as nitrogen (U.S. Environmental Protection Agency, 1996). For nitrite plus nitrate, the maximum concentration of all the samples is 12 mg/L as nitrogen. Seventy-five percent of the agricultural- and urban-stream samples have concentrations of 1.3 and 0.6 mg/L as nitrogen or less, respectively. These concentrations are considerably less than the USEPA (1996) MCL for nitrite plus nitrate, also 10 mg/L as nitrogen.

To avoid excessive algae and other aquatic plant growth, USEPA recommends that total phosphorus be less than

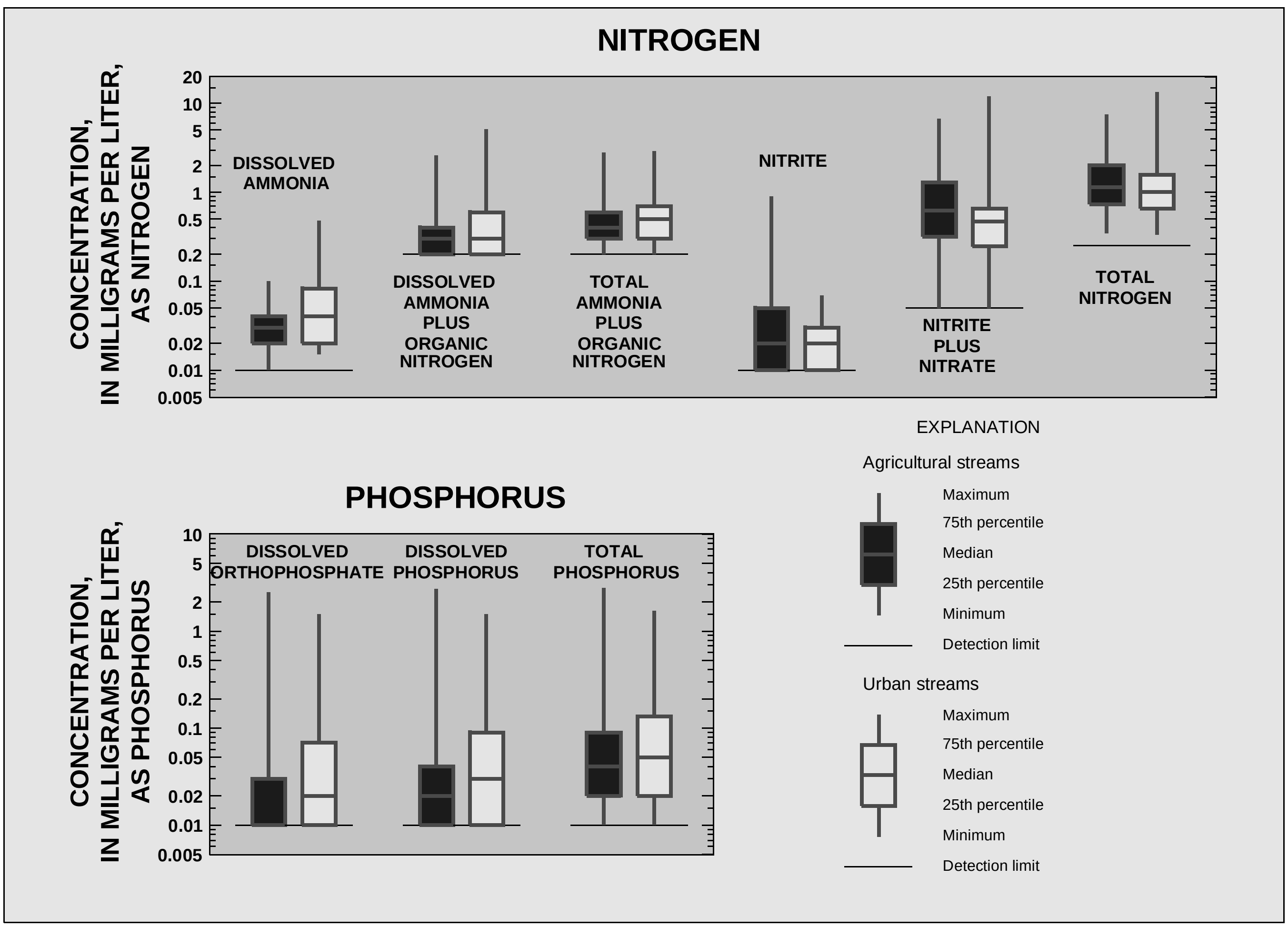

Figure 4. Distribution of nutrient concentrations.

0.1 mg/L in streams except where they enter lakes and reservoirs; there, the concentrations should be less than 0.05 mg/L (U.S. Environmental Protection Agency, 1986). About 20 percent of the samples in the agricultural streams and about 30 percent of the samples in the urban streams have total phosphorus concentrations greater than 0.1 mg/L.

Relation to Seasons

The graphs of total nitrogen and total phosphorus concentrations by date, without regard to year, with LOWESS lines superimposed (fig. 5), allow comparison of seasonal variability in concentration between agricultural and urban streams. For total nitrogen, the LOWESS lines indicate peak concentrations for both types of streams occur in the spring, with concentrations in agricultural streams in the spring commonly higher. Minimum concentrations occur in the summer in the agricultural streams and in the winter in the urban streams.

For total phosphorus, the LOWESS line for agricultural streams shows negligible seasonal variability. The LOWESS line for urban streams shows maximum concentrations in the spring and possibly (based on two data points) late summer, and minimum concentrations in the winter.

Seasonally high concentrations of nitrogen probably are related mostly to the application of fertilizers to fields in the agricultural area and to lawns and landscape plants in the urban area. In the agricultural area, applications begin early in the growing season, even before the crops are planted, and during vigorous plant growth. In the urban area, applications begin when warm weather arrives and continue throughout the growing season (Texas Agricultural Extension Service, written commun., 1995).

Relation to Streamflow

The graphs of total nitrogen and total phosphorus relative to unit discharge (streamflow divided by drainage area), with LOWESS lines superimposed (fig. 6), allow comparison of changes in concentrations as streamflow increases for agricultural and urban streams. Streamflow is represented by unit discharge because of different sizes of drainage basins upstream of the sampling sites.

Concentrations of total nitrogen in the agricultural streams generally increase with increasing streamflow. Concentrations of total nitrogen in urban streams increase with increasing streamflow only in midrange of flow (about 0.001 to 0.01 cubic meter per square kilometer) and change little in the lower and upper ranges of flow.

Concentrations of total phosphorus in both agricultural and urban streams show little variation with streamflow during low streamflow conditions. However,

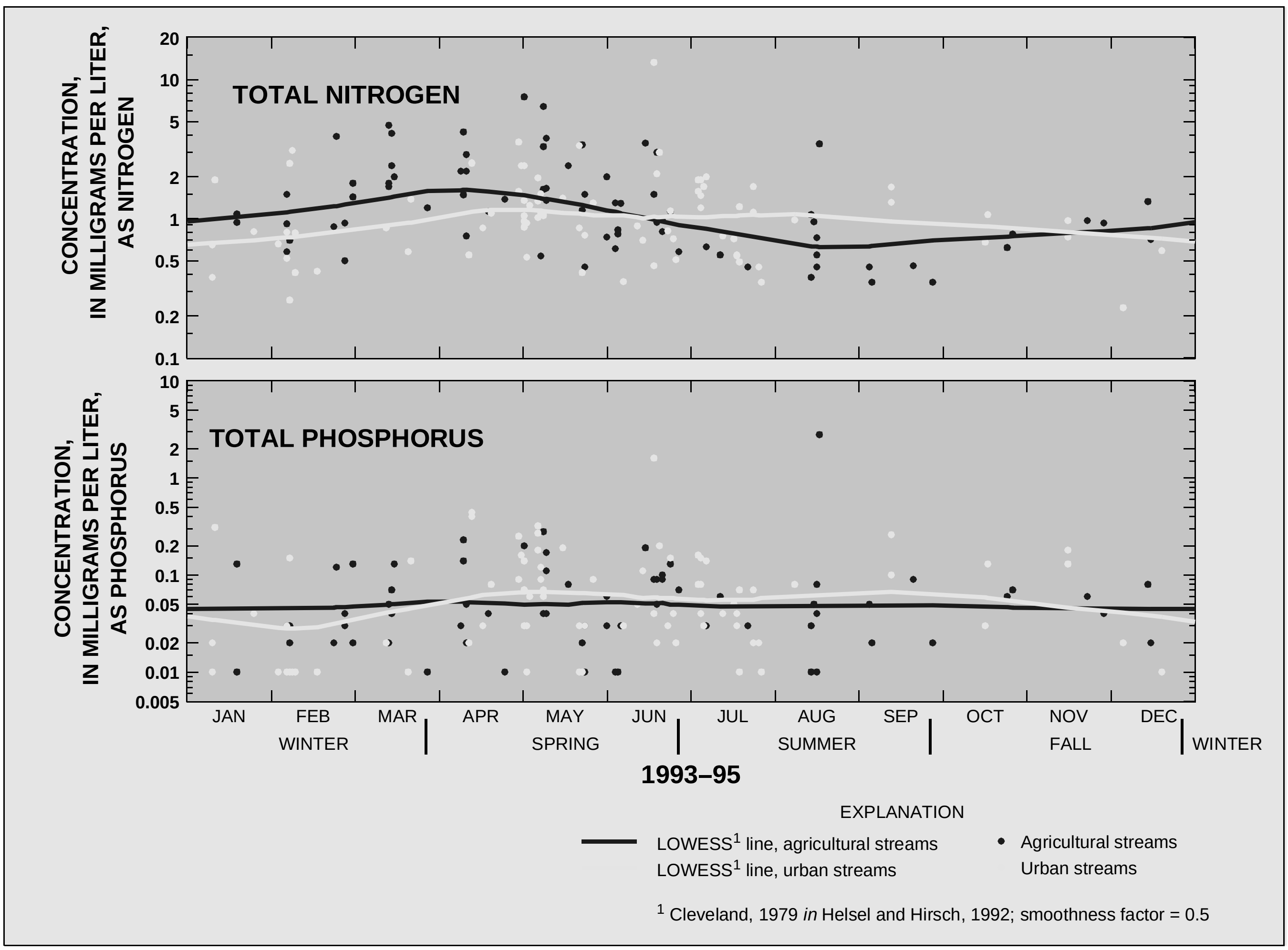

Figure 5. Variability of total nitrogen and total phosphorus concentrations with season.

concentrations increase with increasing streamflow in both types of streams in the middle and upper ranges of flow.

When constituent concentrations increase as streamflow increases, the physical phenomenon responsible is known as washoff. For example, suspended-sediment concentration in streams is directly related to the washoff of soils by overland flow—the more overland flow, the more suspended sediment in the stream. When constituent concentrations decrease as streamflow increases, the physical phenomenon responsible is known as dilution. Based on these phenomena and the concentration-streamflow relations shown in figure 6, the availability of total nitrogen for washoff does not seem to be limited in the agricultural area but does seem to be limited in the urban area. The limited availability of nitrogen in urban areas possibly is a result of washoff from earlier storms or by initial washoff during the sampled event. The availability of total phosphorus for washoff does not seem to be limited in either type of stream. Phosphorus availability probably is attributable to the fact that much of the phosphorus is attached to sediment particles.

Summary

Nonpoint-source contaminants in agricultural and urban streams are of considerable interest to the Trinity River Basin study-unit liaison committee. Excessive nutrient concentrations are of concern. The sampling of streams draining an agricultural area and an urban area for nutrients during March 1993–September 1995 yielded some salient results:

Concentrations—

- All nitrogen compounds have similar (differences of 0.1 mg/L or less) median concentrations in agricultural streams and urban streams. Maximum concentrations, except for nitrite, are greater in the urban streams.
- Dissolved ammonia, dissolved ammonia plus organic nitrogen, and total ammonia plus organic nitrogen have greater 75th-percentile concentrations in the urban streams than in the agricultural streams; nitrite, nitrite plus nitrate, and total nitrogen have greater 75th-percentile concentrations in the agricultural streams than in the urban streams.
- All phosphorus compounds (dissolved orthophosphate, dissolved phosphorus and total phosphorus) have greater median concentrations in the urban streams than in the agricultural streams, but only by 0.01 mg/L or less.
- All phosphorus compounds have 75th-percentile concentrations 1.5 to 2 times greater in the urban streams than in the agricultural streams.

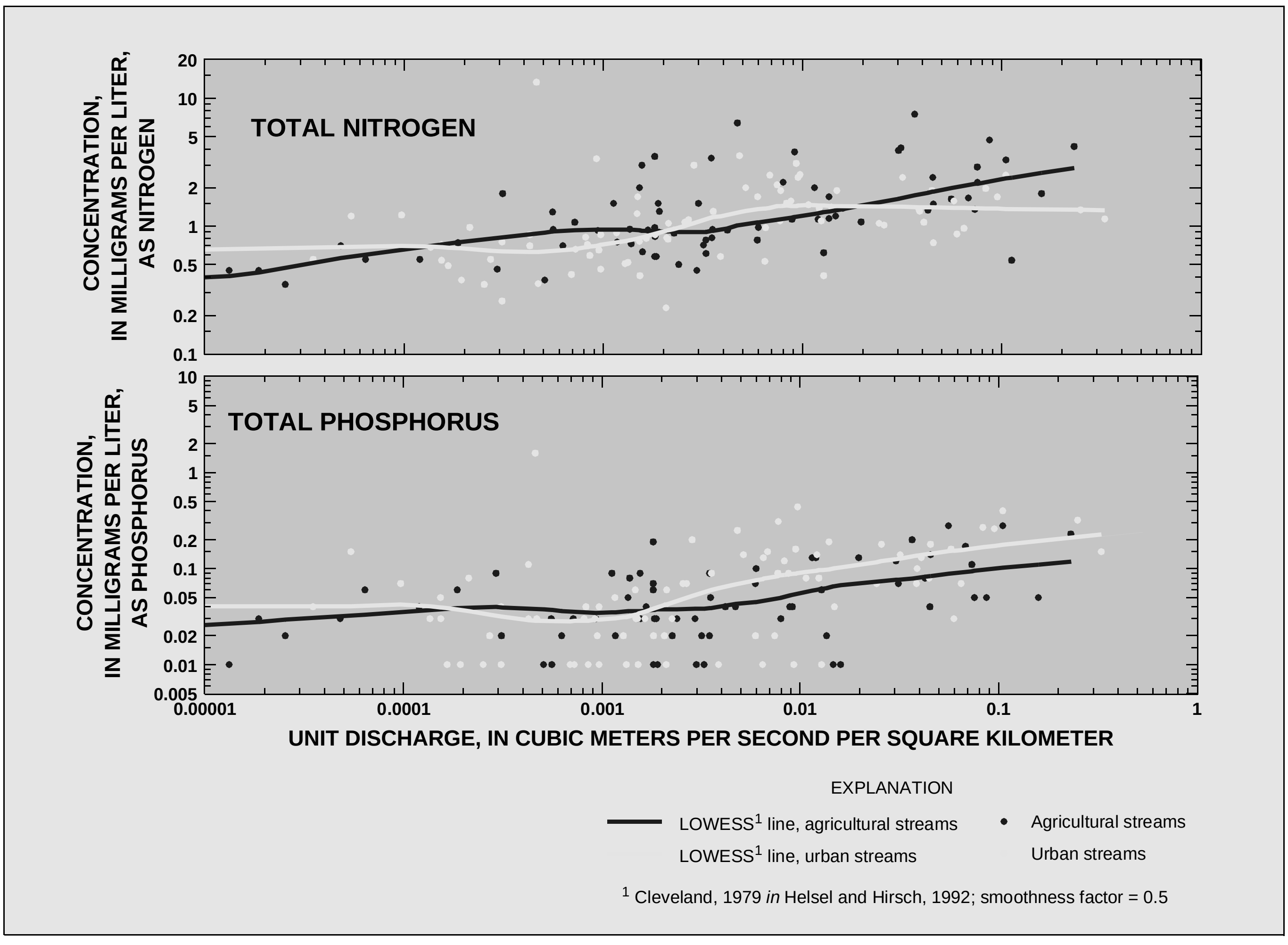

Figure 6. Variability of total nitrogen and total phosphorus concentrations with streamflow.

However, the maximum concentrations are greater in the agricultural streams.

Relation to seasons—

- Total nitrogen concentrations in both agricultural and urban streams peak in the spring, with spring concentrations in the agricultural streams commonly higher.
- Total phosphorus concentrations in agricultural streams show negligible seasonal variability. Concentrations in urban streams appear to be slightly larger in spring, and possibly late summer, than in other seasons.

Relation to streamflow—

- Total nitrogen concentration increases as streamflow increases in agricultural streams throughout the range of streamflow. A similar relation occurs only in the midrange of streamflow in urban streams.
- Total phosphorus concentration increases as streamflow increases in both types of streams in the middle and upper ranges of streamflow.
- The maximum concentration of total nitrogen is from an urban stream; but greater seasonal nitrogen concentrations and greater nitrogen concentrations at high streamflow are from the agricultural streams, rather than the urban streams.
- The maximum concentration of total phosphorus is from an agricultural stream; but greater seasonal phosphorus concentrations and greater phosphorus concentrations at high streamflow are from the urban streams, rather than the agricultural streams.

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In 1991, the U.S. Geological Survey, U.S. Department of the Interior, began a National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the status of and trends in the quality of a large representative part of the Nation's surface- and ground-water resources and to identify the major factors that affect the quality of these resources. In addressing these goals, NAWQA will produce water-quality information that is useful to policymakers and managers at Federal, State and local levels.

Studies of 60 hydrologic systems that include parts of most major river basins and aquifer systems are the building blocks of the national assessment. The 60 study units range in size from less than 1,000 to more than 60,000 square miles and represent 60 to 70 percent of the Nation's water use and population served by public water supplies. Twenty investigations began in 1991, 15 investigations began in 1994, and 20 are scheduled to begin in 1997.